
Subject: Resonances!

Posted by [Martin](#) on Mon, 11 Oct 2004 19:26:53 GMT

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Hi Wayne and akhilesh, I have not been following your thread until this afternoon. Resonances are always of interest so I will chime in with my take on resonances and how they change the driver's impedance curve. If you see a peak in the driver's impedance magnitude curve, and an accompanying rapid phase fluctuation, then this is a sure sign of a resonance of some form. The way I see it is as follows.

1. Driver in free space or in an infinite baffle - a resonance condition will occur at or very near f_s of the driver. There will be a single tall impedance peak along with a phase swing that approaches 180 degrees. $f_s = (1/(2 \times \pi)) \times (k_{ms}/m_{ms})^{1/2}$ k_{ms} = driver suspension stiffness (newton/m) $k_{ms} = 1/c_{ms}$ c_{ms} = driver suspension compliance (m/newton) m_{ms} = driver mechanical moving mass (kg)
2. Driver in a closed box - by adding a closed box to the back of the driver you are adding a second spring in parallel with the driver's suspension and raising the f_s to a new frequency f_c . This is predictable from the equation for the natural frequency of a spring and mass $f_c = (1/(2 \times \pi)) \times ((k_{ms} + k_{mb})/m_{ms})^{1/2}$ k_{mb} = stiffness of the air in the box $k_{mb} = 1/c_{mb}$
3. Driver in a resonant enclosure - by adding a resonant enclosure, either a ported box or a TL tuned to f_b , new resonant frequencies are generated. For a ported box the resonant frequency is determined by $f_b = (1/(2 \times \pi)) \times (k_{mb}/m_{mb})^{1/2}$ k_{mb} = stiffness of the air in the box (newton/m) $k_{mb} = 1/c_{mb}$ c_{mb} = compliance of the air in the box (m/newton) m_{mb} = moving mass of the air in the port (kg)

For a straight classic TL the fundamental resonance is a function of the length $f_b = 1/4 \times c/L$ c = speed of sound (m/sec) L = length of the line (m) with harmonics at $f_b = n/4 \times c/L$ $n = 3, 5, 7, 9, \dots$

The interesting phenomenon occurs when you combine two resonant systems, the driver and the enclosure, having approximately equal fundamental frequencies $f_s \sim f_b$. It does not matter if it is a ported box (bass reflex) or some form of quarter wave enclosure, the behavior of the resulting resonances is the same. When two systems, with approximately equal fundamental resonances are combined, the resulting system will have two new resonances that bracket the original resonances as shown below. $f_{low} < f_s \sim f_b < f_{high}$

The new resonances at f_{low} and f_{high} are the two impedance peaks you see for a bass reflex enclosure and an unstuffed TL. The lower resonance, f_{low} , is the driver moving into the enclosure pushing air out of the open end or port and this produces the 24 dB/octave roll-off of a bass reflex or TL design. The mode shape (vibration theory term - the motion of vibrating systems can be completely described by their natural frequencies and mode shapes) has the driver mass moving into the enclosure and the open end air mass moving out of the enclosure. The higher resonance, f_{high} , is the driver and the air at the enclosure opening moving out of phase combining to produce SPL. As you move up in frequency the driver's output dominates and you get the SPL curve of the driver. The mode shape has the driver mass moving out of the enclosure and the open end air mass moving out of the enclosure. The common misconception is what happens at $f_s \sim f_b$ which is the minimum between the two impedance peaks. This is not a resonance condition in the combined driver/enclosure system. This is the point between the two resonances where the mode shapes combine and result in the driver mass almost stopping (mode shapes cancelling the driver motion) while the motion of the open end air mass combines (mode shapes reinforcing the motion) to be a maximum. When the driver almost stops moving the only significant impedance is the resistance of the voice coil which is the minimum between the two resonant peaks. Adding stuffing to the bass reflex or TL enclosure will tend to damp out the first resonant peak. Many people claim a TL has only one resonance peak which is incorrect. As you add more and more stuffing you tend to

attenuate the lower impedance peak, at f_{low} , resulting in a single humped impedance curve. To determine the number of resonances and mode shapes analyze the system without damping present, for a TL this means empty. 4. Driver in a horn - if the horn is sized correctly it acts as a pure resistance above the lower cut-off frequency f_c . So combining a horn with a driver, when $f_s \sim f_c$, you just add an acoustic resistance to the driver. The resulting impedance curve will have a peak at the driver f_s but it will be lower magnitude and broader. I have included some interesting response curves for horn speaker designs in the recent addition of horn theory on my website. Ok, I am out of time. I hope that helps and I can add more detail if there are specific questions. I typed this up quickly from memory. The boss is on vacation today so it has been a great day! Martin
